Distributed Battle Management
Battle Management at the Tactical Edge

Industry Day

Agenda

Start	End	Topic	Presenter
08:30	08:35	Security	Mike Langerman, DARPA SID
08:35	08:40	Welcome	Craig Lawrence, DARPA PM
08:40	09:00	DARPA STO Overview	Nils Sandell, STO Director
09:00	10:00	DBM Concept	Craig Lawrence, DARPA PM
10:00	10:20	SIMAF Overview	Walt March, SIMAF
10:20	10:40	Short Break	
10:40	11:40	Q&A Session	Craig Lawrence, DARPA PM
11:40	11:50	Closing Remarks	Craig Lawrence

Distributed Battle Management
Strategic Technology Office

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2/28/2014

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    Defense Advanced Research Projects Agency
    ATTN: STO, PSR Michael Langerman
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DARPA Strategic Technology Office
Contested Environment Strategy and Plans

Nils Sandell, Director

February 28, 2014

Strategic Technology Office (STO) Contested Environment Thrust

STO Systems and Technologies: Core Competencies

- Battle Management/Command and Control (BMC2)
- Communications (C)
- Intelligence, Surveillance and Reconnaissance (ISR)
- Electronic Warfare (EW)
- Positioning, Navigation and Timing (PNT)
- System-of-Systems Integration

STO Contested Environment Thrust: Focus Areas

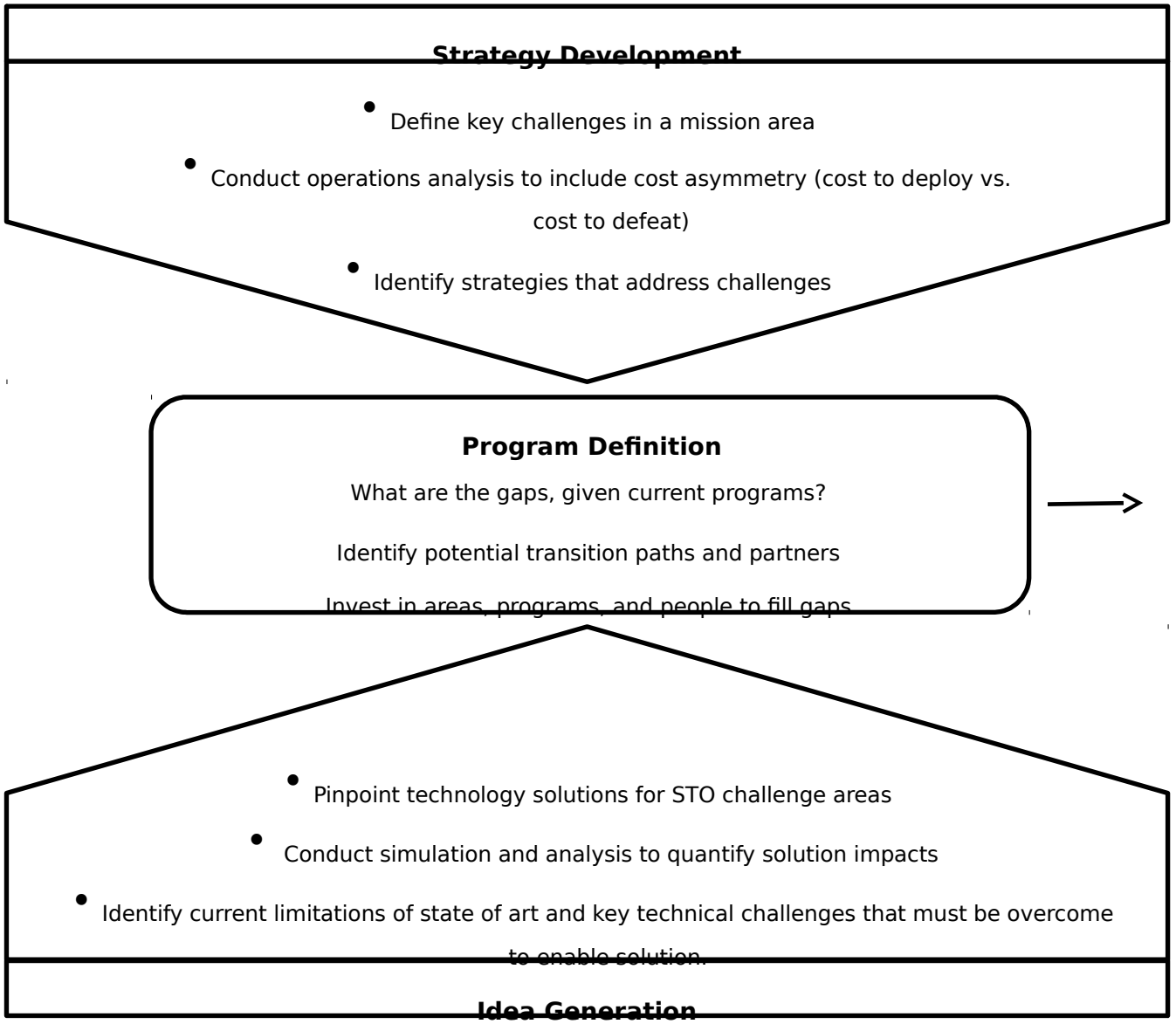
- Air Dominance against Peer Threat
- Undersea Dominance against Peer Threat
- Spectrum Dominance against Peer Threat

Fighting as a Network to Increase

Military Effectiveness, Cost Leverage, and Adaptability

Program Definition Combines Strategy Development (Top Down) with Idea Generation (Bottom Up)

- National, Defense Strategies
- COCOM, Service Needs
- DARPA Investment Themes
- AEO, Liaison Staff, Special Assistant Input, ADI



- DSO, I2O, MTO, TTO
- Universities
- Industry
- Government Labs and FFRDCs

Contested Environment Thrust
Goals and Potential Approaches

- Goals: Technologies to Help Enable
  - Air, Undersea and Spectral Dominance* Against Peer Threat
  - Agile Insertion of New Technology
  - Positive Cost Leverage

- Potential Approaches
  - Networking of Low Cost Autonomous Platforms with Manned Platforms
  - Electronic Warfare and Electronic Counter-Counter Measures
  - Electro-Optical (EO) Systems
  - Agile, Jam-Resistant Sensing and Navigation
  - Low Probability of Detection/Anti-Jam Communications
  - Distributed, Deep Ocean Active and Passive Sonar
  - Underwater Operations

*Dominance limited in time and space

Contested Environment Challenges and Strategies – BMC2

- BM/C2 Challenges
  - Integrated strike, communications, ISR and EW planning and real-time control for piloted/unmanned, air/surface/subsurface platforms
  - Rapid response to pursue ephemeral engagement opportunities
  - Mission- and not just vehicle-level autonomy
  - Robustness to limited communications and platform attrition
  - Development of user-appropriate technology and acceptance of automation by C2 personnel

- BM/C2 Strategies
  - Adaptable software incorporating distributed algorithms and protocols
  - Experimentation to determine optimal human roles as dictated by situation and Concept of Operations (CONOPS)
  - Coevolution of CONOPS and technology

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Distributed Battle Management
Battle Management at the Tactical Edge

Craig Lawrence, STO Program Manager

Industry Day Presentation

28 February 2014

DISTRIBUTED BATTLE MANAGEMENT (DBM) PROGRAM OVERVIEW

DBM: Distributed Battle Management

- **CONTEXT** - Peer threat drives a system of systems approach incorporating innovative technologies into the kill chain
  - Innovative and diverse networked technology integrated with legacy systems

- **PROBLEM** – Managing proposed systems of systems with today's battle management requires
  - Coordinated effort by operators and pilots with minimal automation aids
  - Robust network for task coordination and exchange of situation understanding

➢ *Severe challenge for operators and pilots to manage complexity and scale*

➢ *Communications not assured in contested environments*

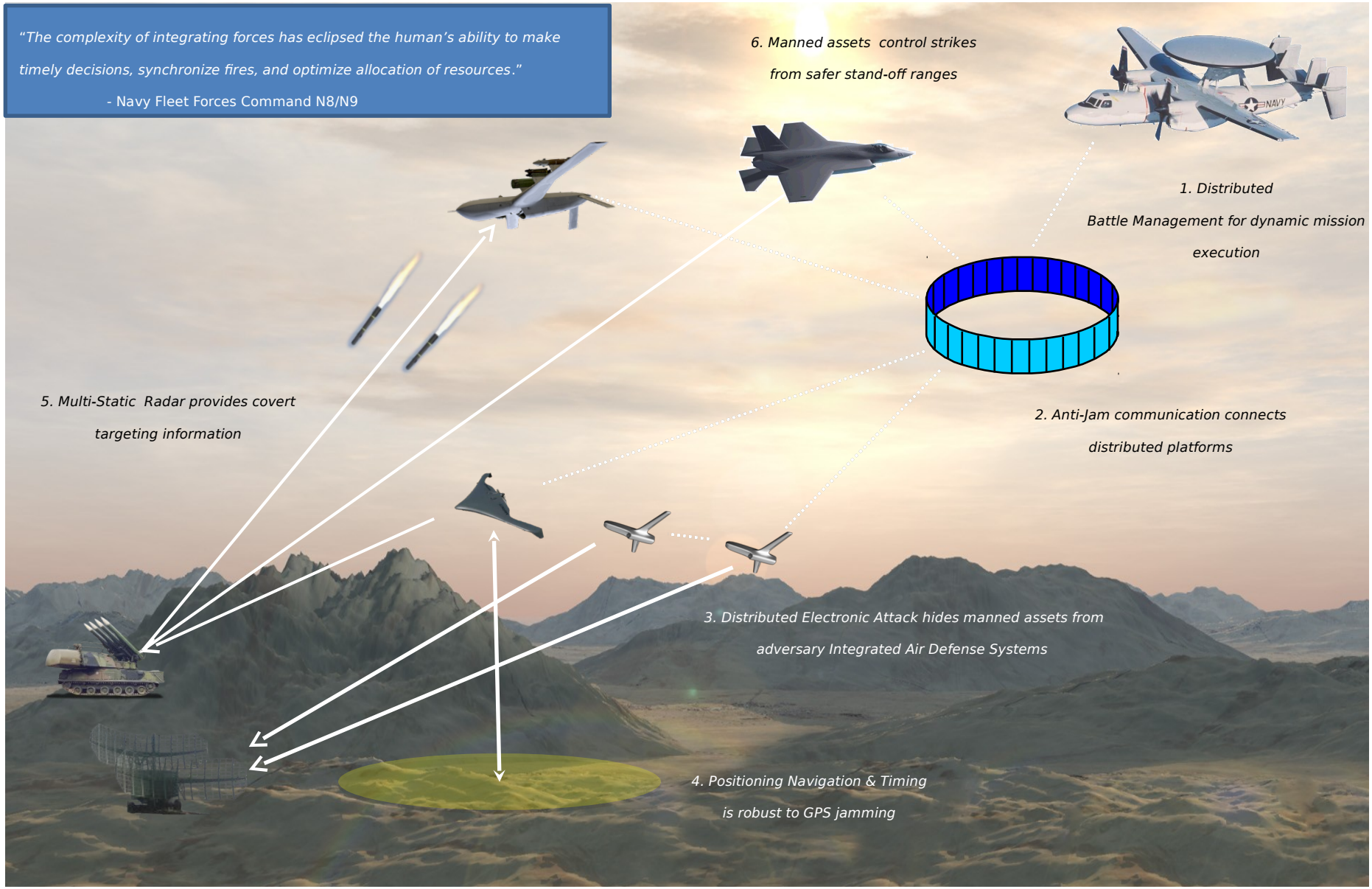
- **SOLUTION** – Algorithms and software to assist operators and pilots

DBM will develop control algorithms and demonstrate robust decision aid software for battle management at the tactical edge

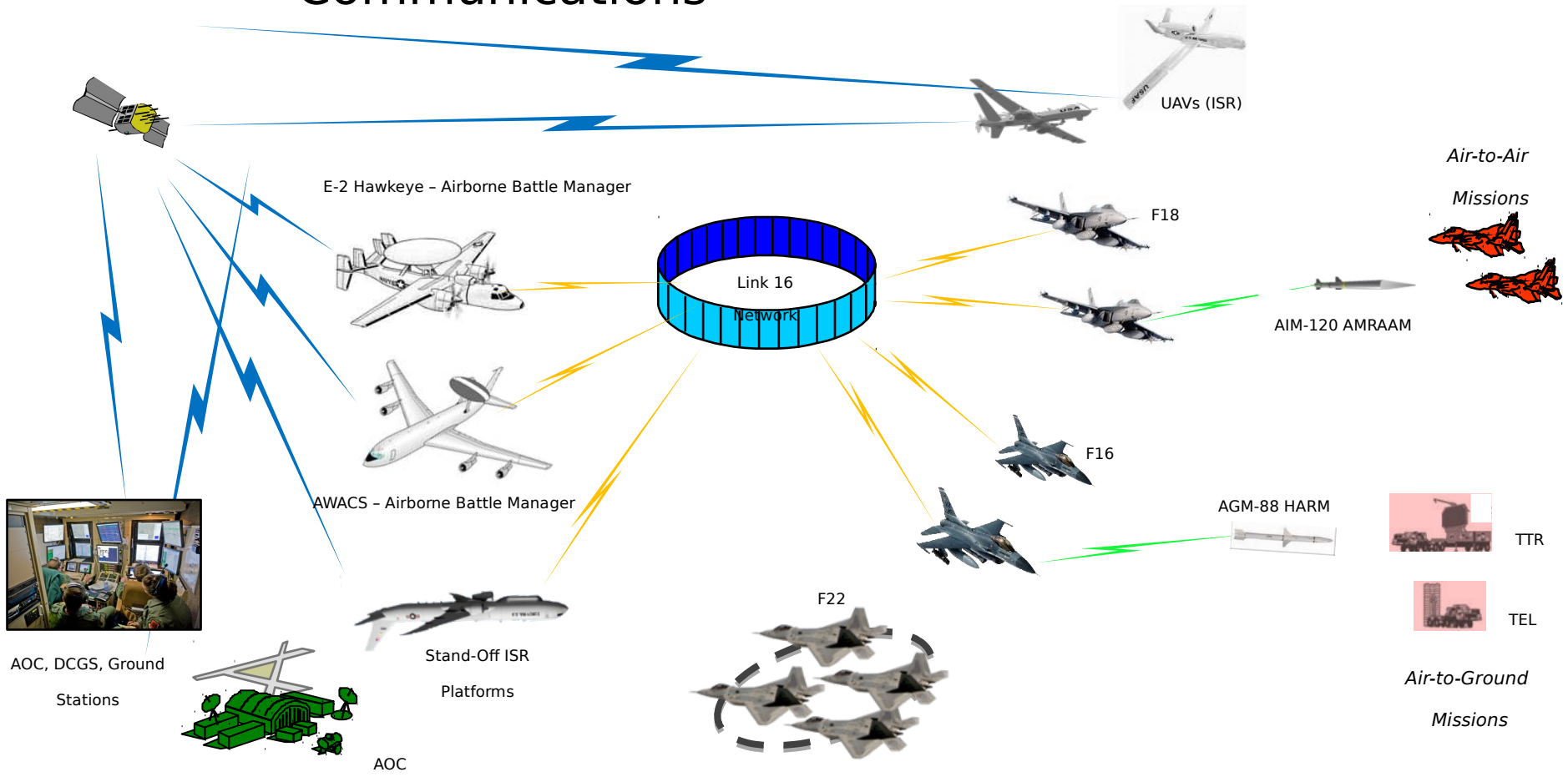
Systems of Systems Multiply the Complexity of the Management Problem

"The complexity of integrating forces has eclipsed the human's ability to make timely decisions, synchronize fires, and optimize allocation of resources."

- Navy Fleet Forces Command N8/N9



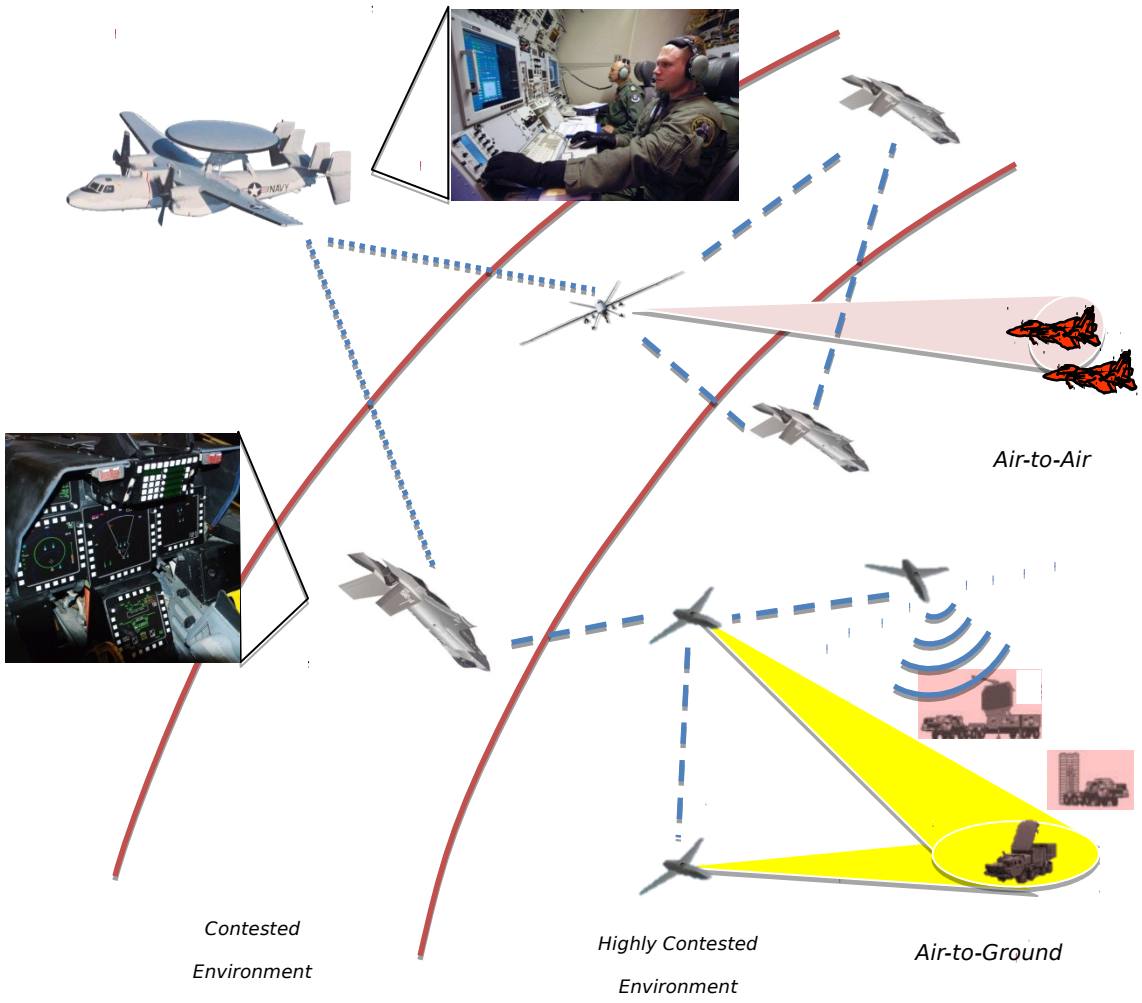
Today's Battle Management is Manual and Depends on Reach Back and Robust Communications



AWACS = Airborne Warning And Control System	ISR = Intelligence, Surveillance, and Reconnaissance
AMRAAM = Advanced Medium Range Air-to-Air Missile	TEL = Transporter Erector Launcher
AOC = Air Operations Center	TTR = Target Tracking Radar
DCGS = Distributed Common Ground Station	UAV = Unmanned Aerial Vehicle
HARM = High-speed Anti-Radiation Missile	

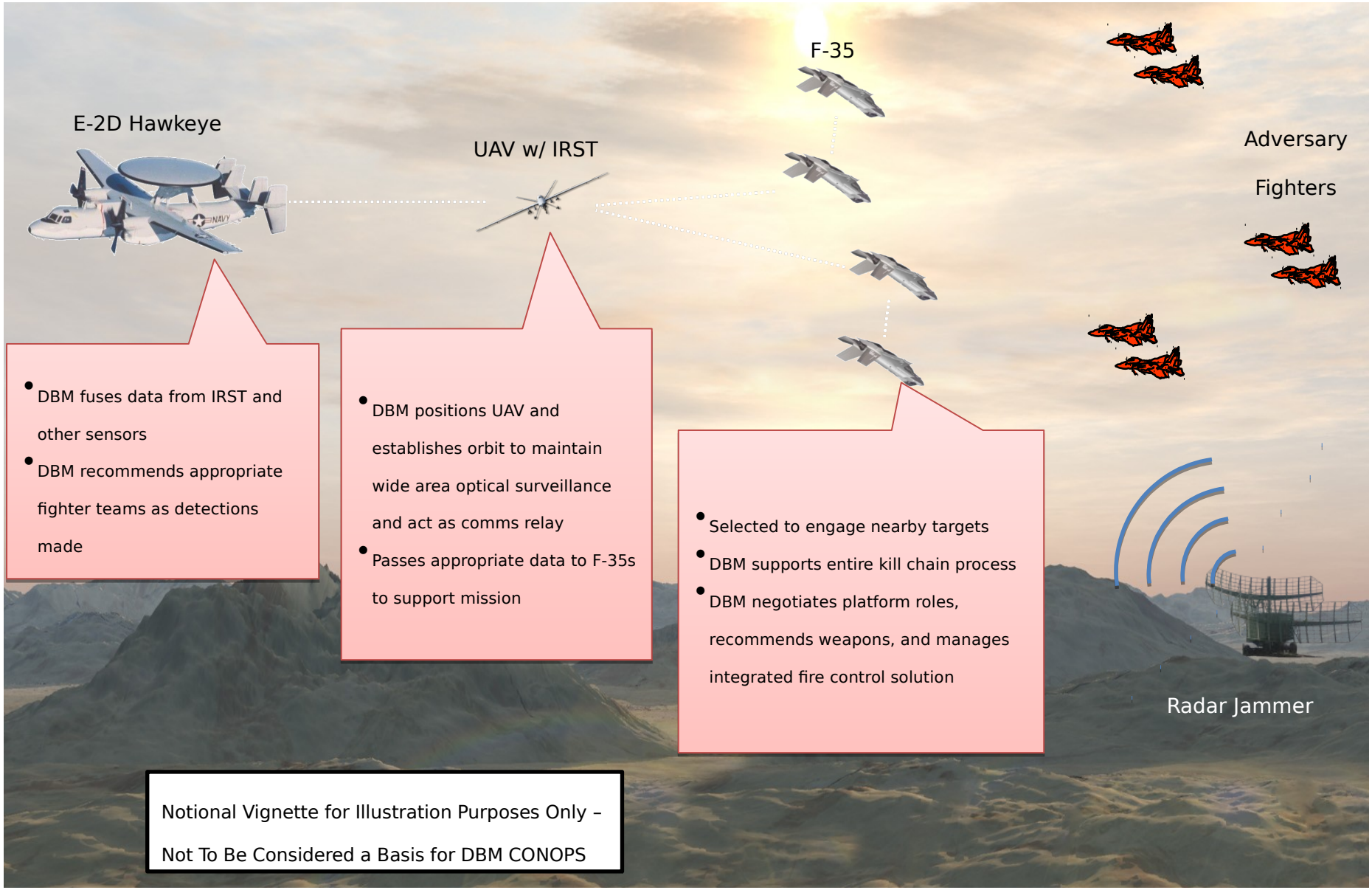
Pushing Battle Management to the Tactical Edge Enables Innovative CONOPS in Contested Environment

- System of Systems (SoS)
  - Architecture incorporating innovative technologies and legacy capabilities
  - Disaggregated and fractionated capabilities
- DBM Challenges
  - Distributed Adaptive Planning and Control
  - Distributed Situation Understanding
  - Human-Machine Integration

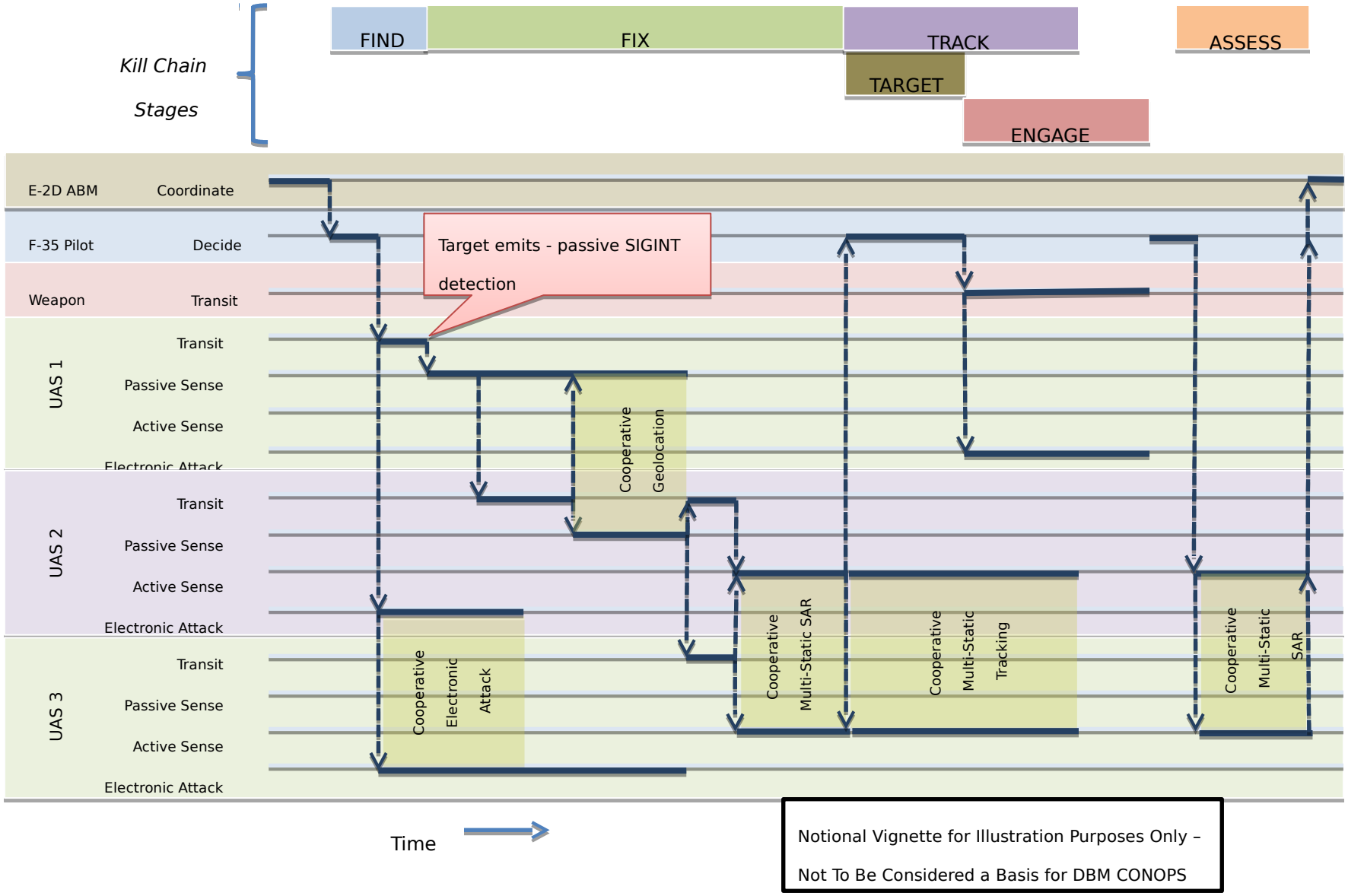


Battle Management Algorithms and Software Needed to Help Pilots and Operators Manage Scale and Complexity with Limited Communications

Illustrative Vignette – Air-to-Air

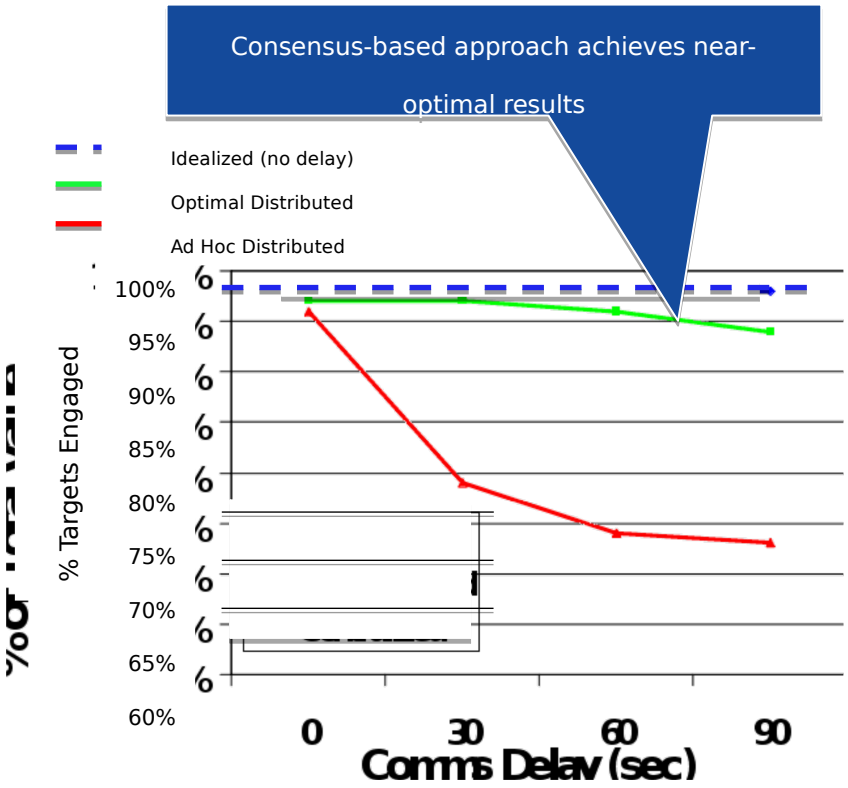


Illustrative Vignette – Air-to-Ground



Challenge: Distributed Adaptive Planning and Control Manages Resources

- Planning and control of platforms and mission systems
- Available Technology
  - Optimization-based weapon-target pairing, asset routing, and ISR scheduling
  - Autonomous coordinated control - centralized planning w/ assured comms
  - Collaborative teaming in comms limited environment
- DBM Program
  - Robust real-time implementations of algorithms
  - Integration into on-board software
  - Demonstrate in realistic peer threat environment – simulation and live fly



- AFRL distributed control program
- 4 Air Vehicles Against 32 SAMS and 16 C2 Facilities
- Comms model: Link 16 with parameterized delays

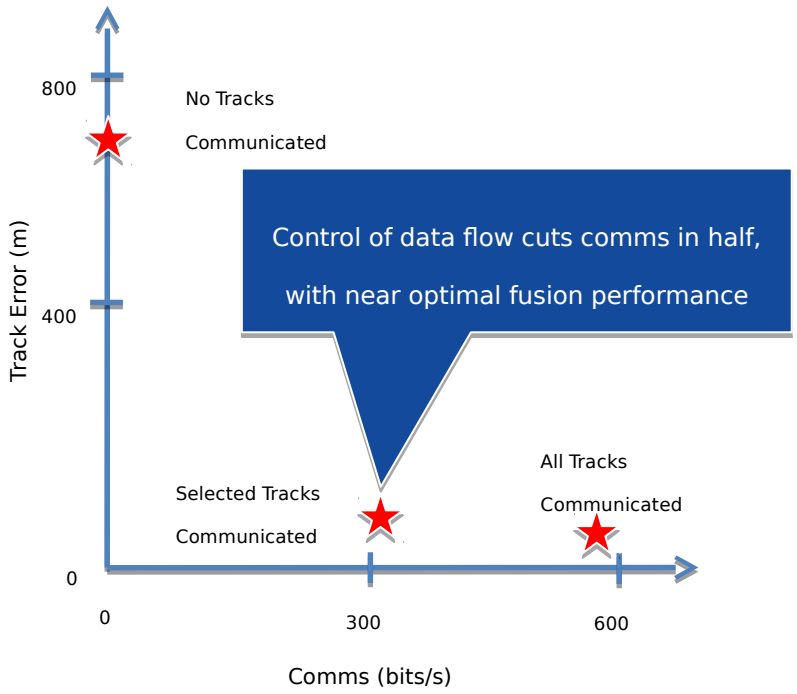
Near Optimal Planning Can Be Achieved at the Tactical Edge

Challenge: Distributed Situation Understanding Develops Dynamic Estimates of the Situation

- Estimate blue and red force position, ID, and status

- Available Technology
  - Multi-hypothesis and graph-based tracking and fusion algorithms
  - Distributed data fusion algorithms
  - Consensus algorithms for distributed decision making

- DBM Program
  - Robust real-time implementation of algorithms – emphasis on data sharing problem
  - Integration into on-board software
  - Demonstrate in realistic peer threat environment – simulation and live

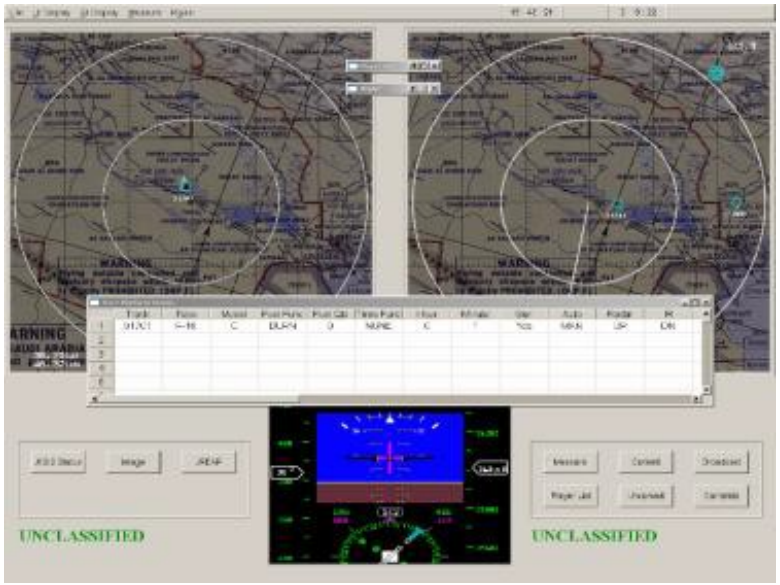


David Akselrod, et al., "Information Flow Control for Collaborative Distributed Data Fusion and Multisensor Multitarget Tracking," *IEEE Transactions on Systems, Man, and Cybernetics*

Common Operational Picture Constructed with Reduced Comms

Challenge: Human-Machine Integration (HMI) for Situation-Dependent Level of Control

- Enable operator and pilot teams to quickly
  - Comprehend situation
  - Manage kill chains
- Available Technology
  - Mixed-initiative planning
  - Multi-function displays
  - Adaptable autonomy
- DBM Program
  - Experimental effort to determine pilot / operator role
  - Determine information needed to support role
  - Displays to best present information and enable control

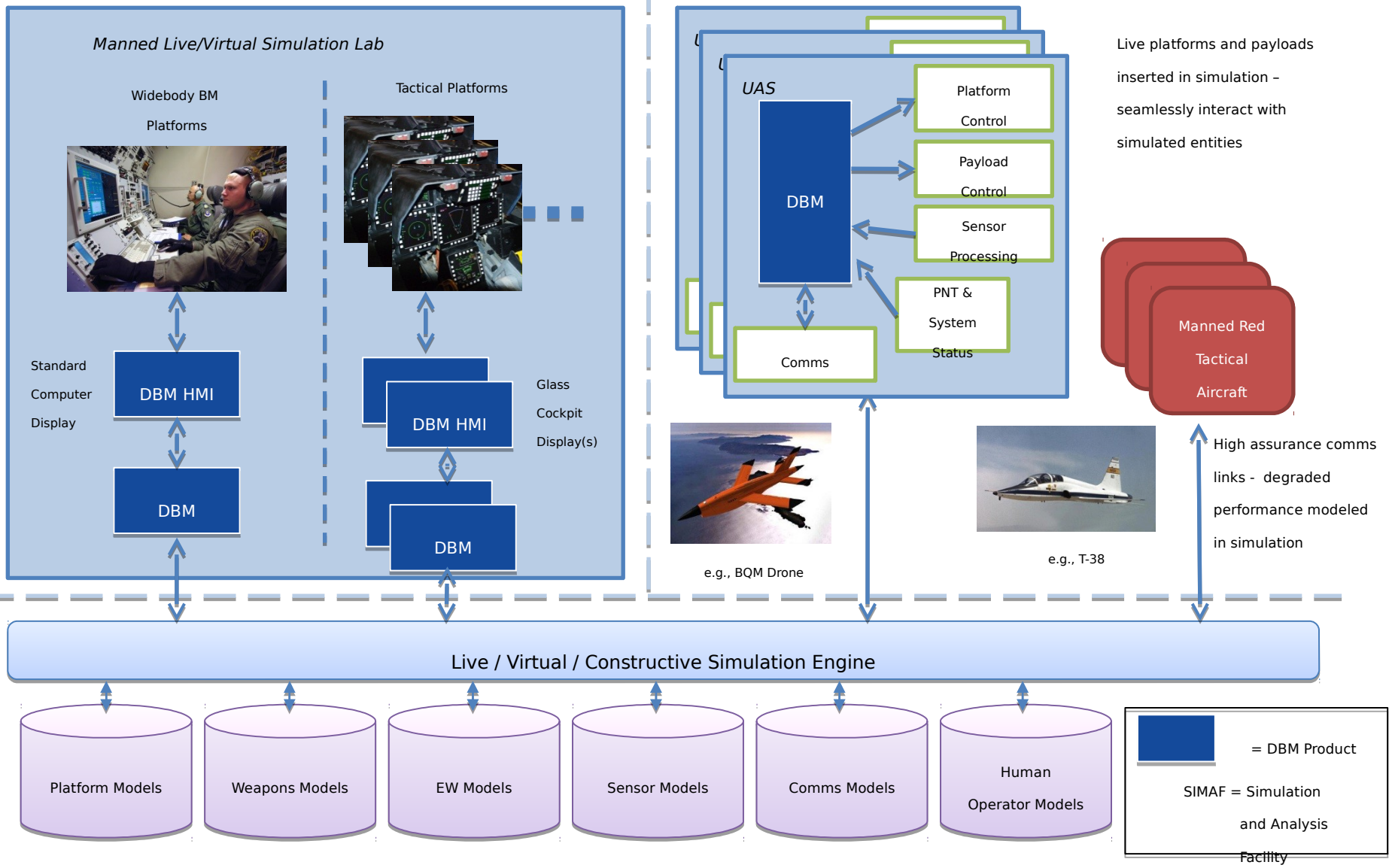


Managing the Battle from a Tactical Platform

The Systems Integrator Will Make the DBM Concept a Reality

- Systems Engineering
  - CONOPS and Requirements
  - Functional Decomposition and Architecture
  - Interface Descriptions
    - Including Message Sets for Integration into On-Board Software
- Software Framework for Integration of Algorithms into On-Board Software
- Integration and Test
- Conduct Live / Virtual Demonstrations
  - Provide the platforms

Test Environment Enables Integration of Live and Virtual – Leverage Existing Capabilities (e.g., SIMAF)



DBM Metrics and Goals Will Be Refined By Government Team Based on Calibrated Baseline Scenarios

Metric Class	Examples
Mission Effectiveness	Missions effectiveness (e.g., targets prosecuted) relative to effectiveness in permissive communications environment for government-defined scenario
Situation Understanding	Ratio of average target error relative to average target error in permissive environment for government-defined scenario
Capacity	Number of aircraft managed during real-time execution
Operator / Pilot Workload	Number of operators required for battle management, percentage of time spent interacting with DBM tools
System Flexibility	Time required to update software for new capability (aircraft, sensor, technique, etc.)

Transition is a Challenge for a Disruptive Capability – Developing a Strategy Now is Essential

- Develop solutions compatible with emerging service standards to enable integration of program's mission applications on platforms
  - Air Force / Rapid Capability Office (RCO) - Open Mission Systems (OMS)
  - Navy PMA 209 - Future Airborne Capability Environment (FACE)

- Build engaging relationships with key stakeholders - cultivate the operational imperative & concepts
  - Start now – before contract award to help shape program direction
  - Invite participation in program e.g. defining challenge problems; supporting demonstrations / experimentation; providing ops inputs to integrated product teams

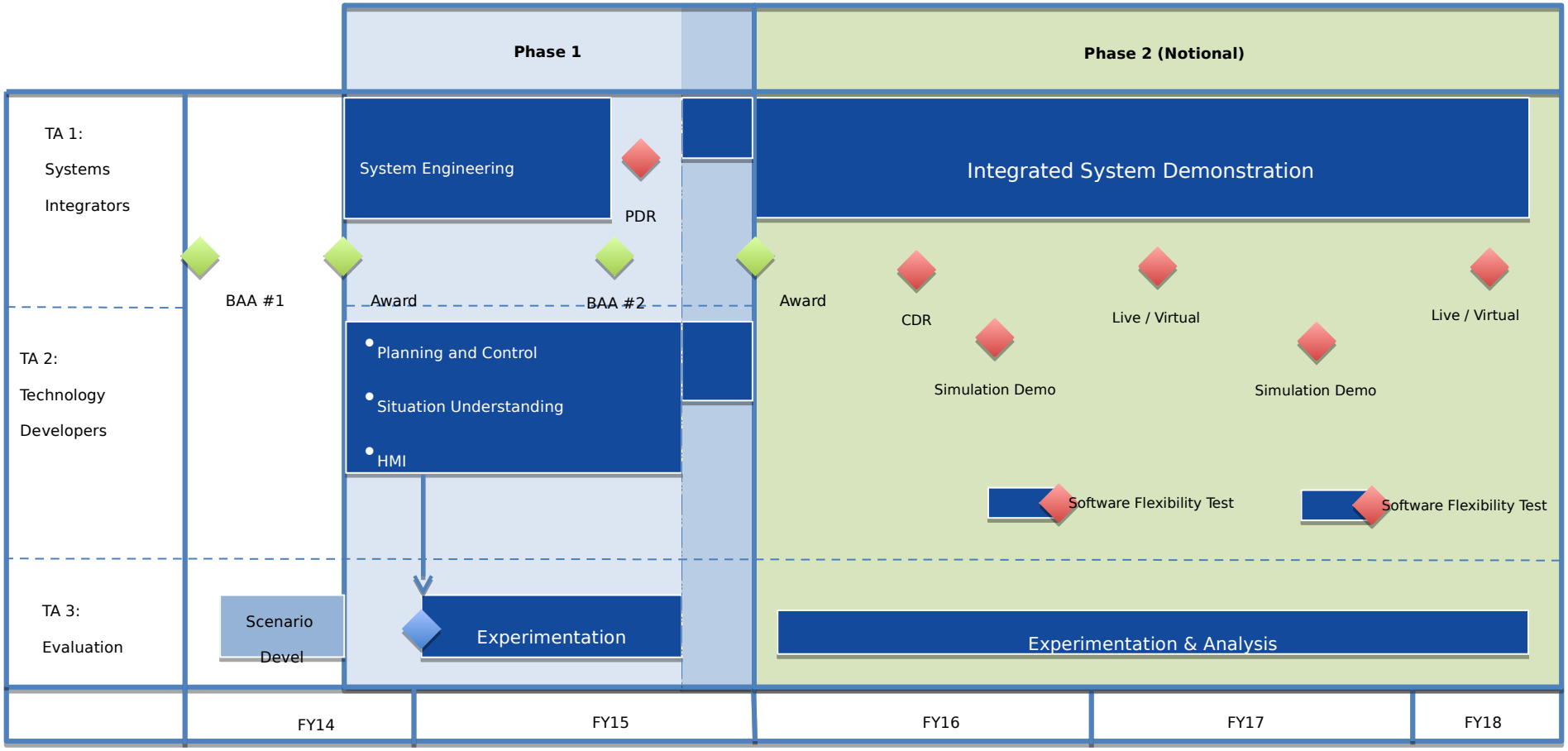
Work with Operators and Pilots From Day One to Ensure We are Solving the Right Problems and on Track for Transition

PHASE 1 DETAILS

Phase 1 Emphasis Is on Design and Development of Critical Enabling Technologies

- Technical Area 1 - DBM Systems Integration
  - Concept of Operations
  - Requirements
  - Design – Allocated Baseline
  - Technical Plan
  - Risk and Cost Analysis
- Technical Area 2 - DBM Technology Development
  - Identify Best-of-Breed Algorithms and Refine For Robustness and Integration
    - Distributed Adaptive Planning and Control
    - Distributed Situation Understanding
    - Human-Machine Integration – Work with Users to Develop Prototypes
  - Rigorous Simulation-Based Testing in Increasingly More Complex, Realistic Environments

Program Plan



PDR = Preliminary Design Review

CDR = Critical Design Review

System Integrator: Phase 1 Culminates in a Preliminary Design Review

- Allocated Baseline
  - All system-level functional performance requirements
  - All external interfaces to the system
  - All internal interfaces of the system
  - Verification requirements
  - Design constraints
- Technical Plan
  - Integrated Master schedule for Phase 2
  - Performance metrics and performance goals
  - Capability increments
  - Trade studies
  - Software development plan
- Review Trade Study Results
- Risk and Cost Assessments

System Integrator: Phase 1 Deliverables

- REVIEW 1 – Month 1

  Program Kick-Off

  - REVIEW 2 – Month 4

  DBM Conceptual Design Review (CoDR)

  - REVIEW 3 – Month 7

  DBM System Requirements Review (SRR)

  - REVIEW 4 – Month 11

  DBM Preliminary Design Review (PDR)

The final deliverable for Phase 1 will be the Phase 1 Final Report, due in month 12.

Technical Interchange Meetings (TIMs) will be held concurrent with these reviews and will include the TA2 performers.

Technology Developers: Phase 1 Schedule, Deliverables

- Program Kick-Off
  - Month 1
  - Performers present proposed technical approach and program plan
  - Government plans to present challenge problems and scenarios
- Quarterly Reviews and TIMs
  - Reviews nominally in months 4, 7, and 11
  - Reviews held in conjunction with program-wide TIMs
    - TIMs will be open to TA 1 System Integrators
- Experimentation / Software Deliverables
  - Software deliveries to government testbed – schedule TBD
  - Testbed ICDs will be developed jointly with government and performers
  - Final software delivered to government at end of Phase 1
- Final Report

Technology Developers: Phase 1 Objectives (1 of 2)

- All TA 1 Performers
  - Support development of interfaces between
    - Distributed Adaptive Planning and Control
    - Distributed Situation Understanding
    - HMI
    - Testbed
  - Support experimentation at government testbed

- Distributed Adaptive Planning and Control Objectives
  - Develop algorithms and software to
    - Determine / negotiate tasking authority based on situation
    - Assign / negotiate roles to platforms
    - Route assets
    - Weapon-target pairing
    - Payload scheduling (sensors, EW, …)
    - and more…
  - Support local decision-making in near real time
  - Support task execution level autonomy for unmanned systems

Technology Developers: Phase 1 Objectives (2 of 2)

- Distributed Situation Understanding
  - Develop a representation of the state information (blue force and red force) required to support distributed battle management planning and control.
  - Investigate and implement appropriate fusion and tracking algorithms
  - Develop protocols regarding what data should be communicated, to whom it should be communicated, and when it should be delivered
  - Design techniques for processing data locally in order to minimize the amount of data to be transferred.

- Human-Machine Integration
  - Design displays and iterate with operators and pilots
  - Emphasis is on using existing displays in airborne battle management and fighter platforms – no new hardware
  - Integrate prototypes into existing airborne battle management terminals and tactical platform multi-function displays (glass cockpit mock-ups)

Security Highlights

- The government expects the majority of the work to be performed at the SECRET level
  - Performers should have facilities and personnel cleared to support development at that level
- Key elements of the security strategy
  - UNCLASSIFIED - Association of general problem formulation classes (as defined in the open literature) with the DBM program
  - UNCLASSIFIED - Algorithms for solving problems in classes identified as relevant for DBM when not tailored for military capabilities or scenarios
  - SECRET - Problem formulation, solution design, and algorithm development when tailored to military capabilities (real or representative) and scenarios
  - SECRET (or higher) - Information revealing DBM system operational performance
- It is highly desirable for performers to have at least one person clearable to the TS//SCI level

Submission Highlights

- Abstracts
  - DARPA will be accepting 5-page abstracts – highly encouraged!
  - Opportunity to receive feedback in advance of committing to full proposal
- Proposers May Bid on Both TA 1 and TA2
  - Must submit separate proposals
  - Multiple thrusts in TA 2 may be combined into one proposal
- Evaluation Criteria
  - Overall Scientific and Technical Merit
  - Potential Contribution and Relevance to the DARPA Mission
  - **Realism of Proposed Schedule**
  - **Proposer's Capabilities and/or Related Experience**
  - Cost Realism

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SIMAF Overview

6 February 2014

Timothy Menke,

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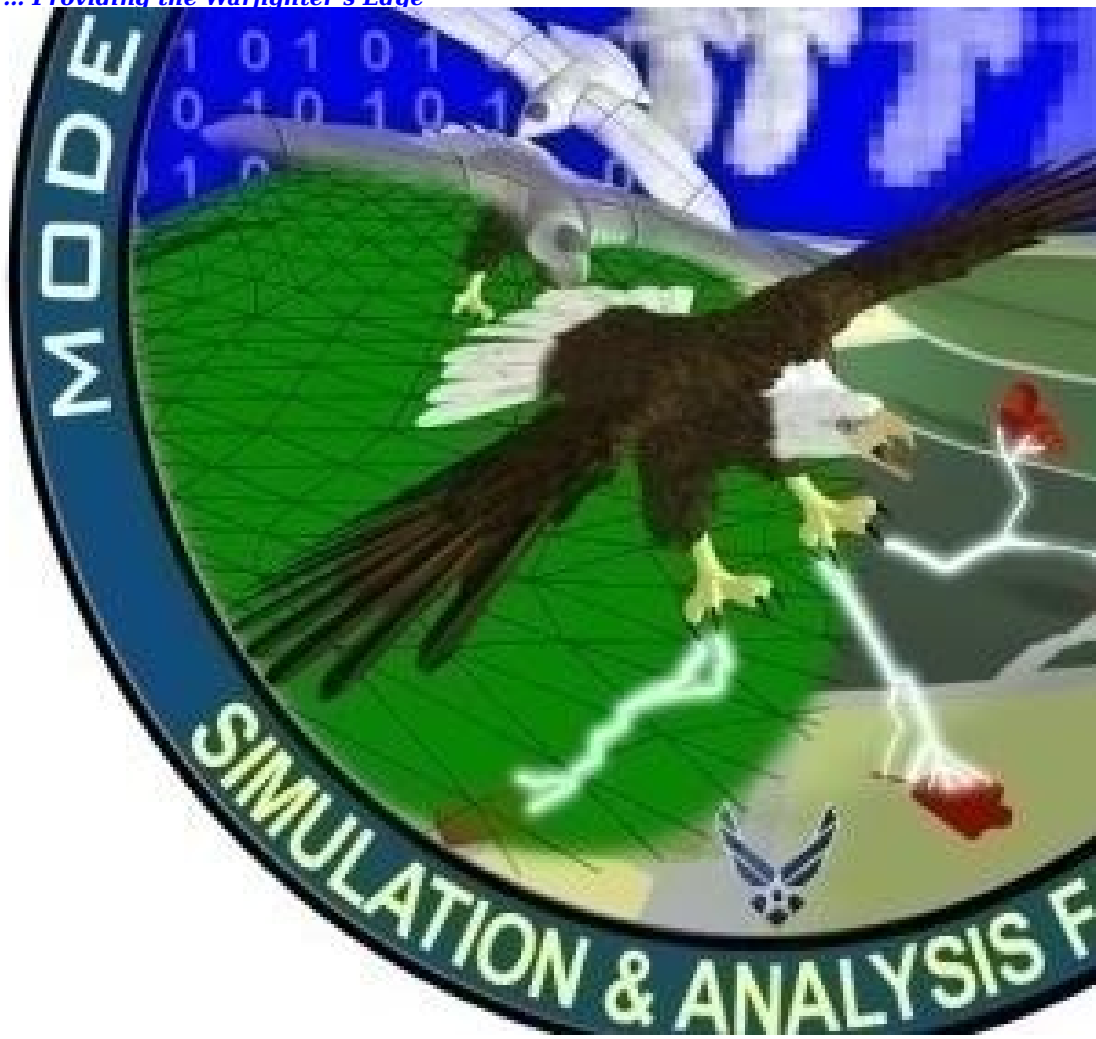
Outline

- **Overview**
  - Mission
  - Analysis Cycle
  - Capability Focus
  - SE Processes
- **Projects**
  - ANI repository
  - ISR data repository
  - Human Interfaces
- **Vision**
  - Where we are headed & Why?
- **Summary**



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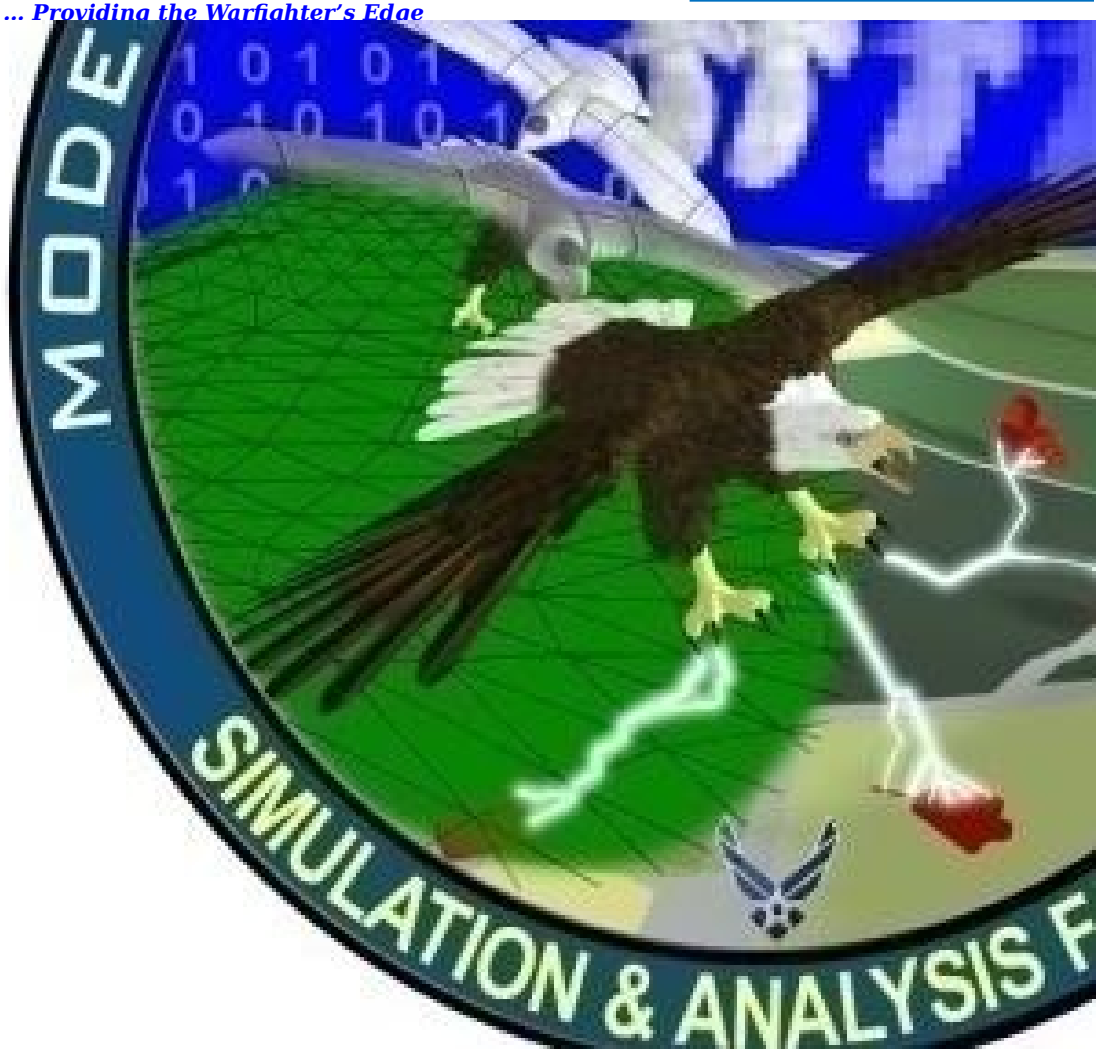


Overview

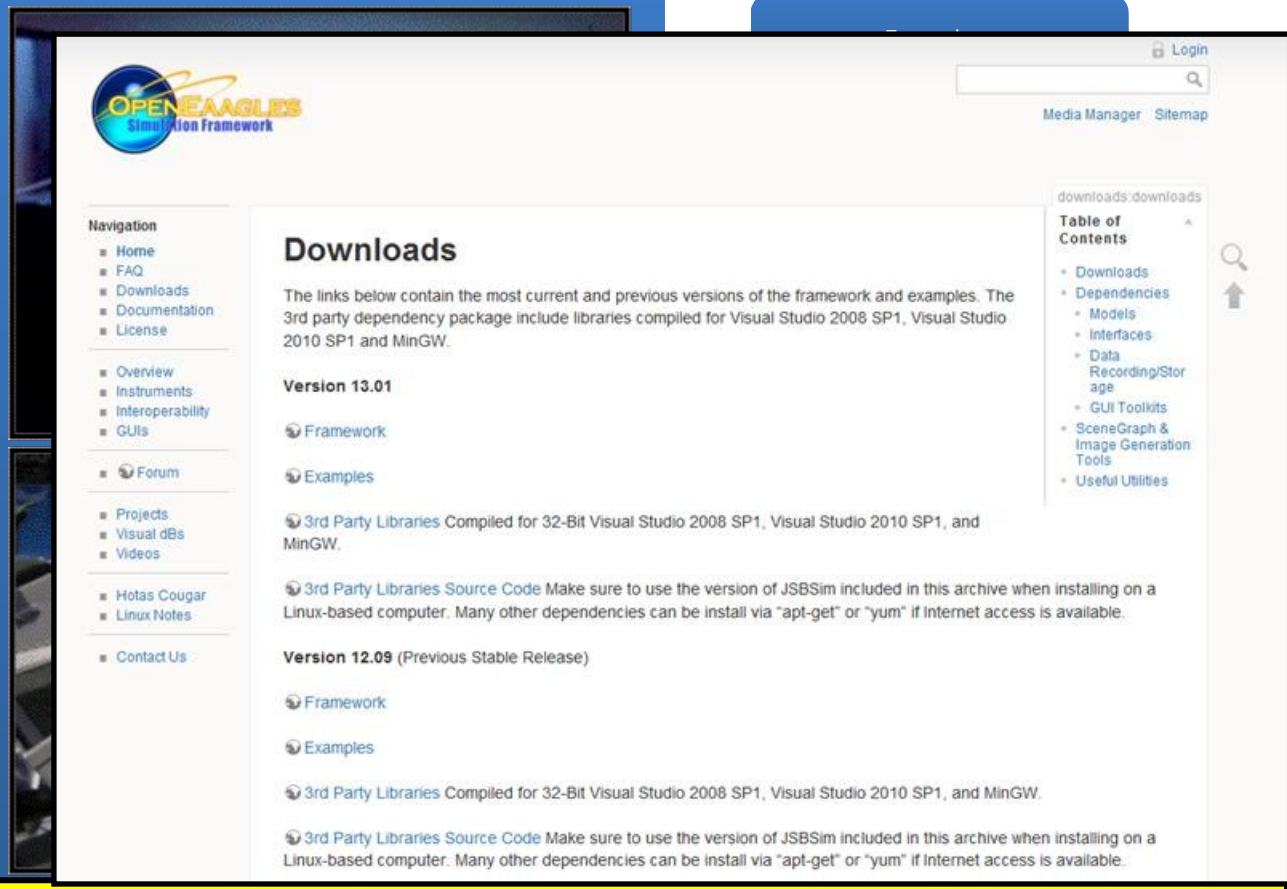
SIMAF Mission

AFLCMC … Providing the Warfighter's Edge

Mission: SIMAF provides a real-time, high-fidelity, virtual and constructive synthetic battle space analysis capability to evaluate:

Human System Interfaces

Strategies, CONOPS & TTPs

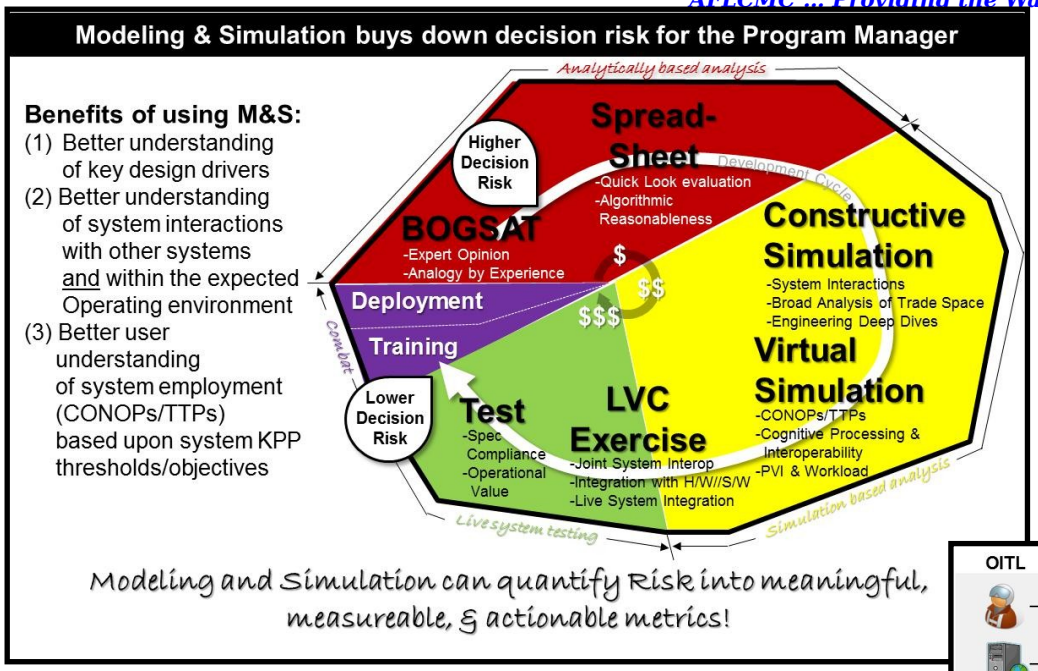


SIMAF utilizes a government owned real time M&S framework known as "EAAGLES"

released to the public under a DOD Open Source initiative: www.openeaagles.org

Overview
Analysis Cycle

AFLCMC … Providing the Warfighter's Edge

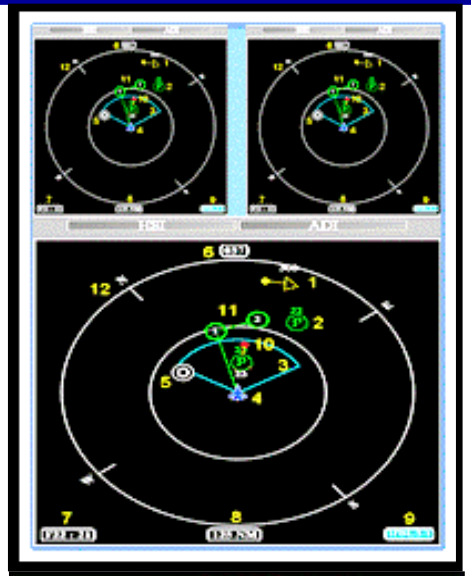


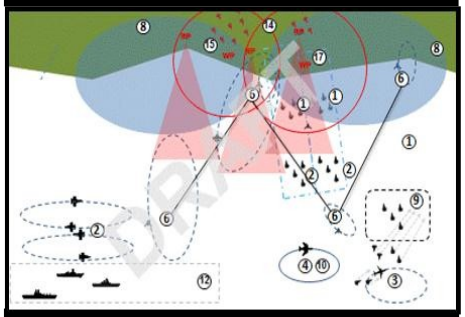
- **Analytically Based**
- **Ops Research Foundation**
- **Executed using a proven System Engineering Process**
- **Designed around a Government Owned, Non-Proprietary, PC Based, Real-Time, C++, Object-Oriented framework**

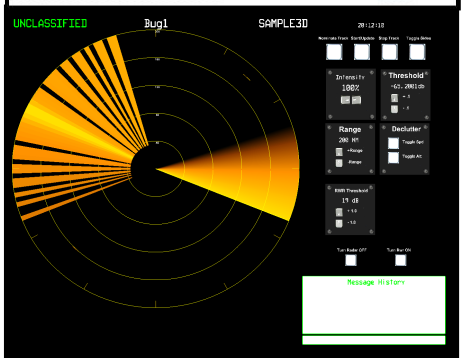
OITL	Type of Study	Study Purpose	Output
	Mission Effectiveness	Quantify system/sub-system and/or capability contribution to mission success	Mission effectiveness measures (MOE/MOPs) by system within a System of System (Lethality, Survivability, Vulnerability)
	CONOPS & TTPS -Development -Refinement	Explore system employment options, quantify results	Improved CONOPS/TTPs, collaborative CONOPS/TTPs for a System of System Capability
	Interoperability	Quantify the performance & contribution to mission lethality, survivability via data transport, fusion, and application	Value to the Operator of Blue Fused Information, Effect of network performance on blue fusion: Level 1: To meet lethality objectives Level 2: To meet survivability detection
	Human System Interface	Support PVI design requirement trades	PVI requirements, utilization and quantification of PVI to support mission objectives, Workload, SA
	Network Scaling Studies	Quantify network performance under expected combat mission loads	Network performance measures under numerous network loads and utilizing numerous mission based applications

Proven the process and framework through the building of Airborne networking applications (models) and network topologies to support our customers analytic objectives

SIMAF Overview







Capability Focus Areas

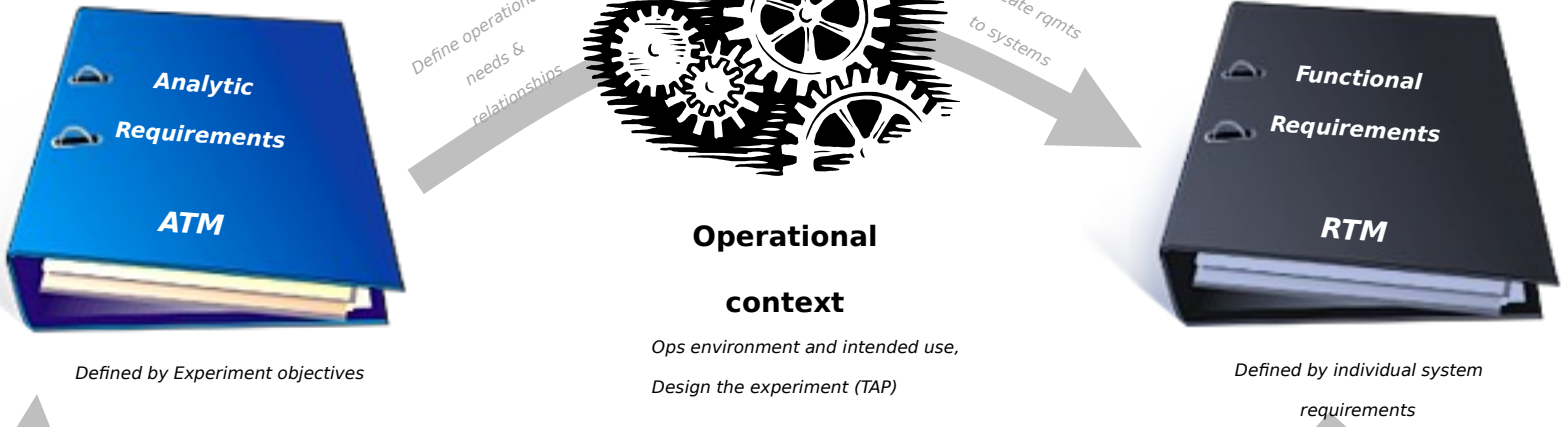
- **Interoperability**
  - Blue Force Communication Compatibility
- **Net Centric Warfare**
  - Blue Force Integrated Mission Effectiveness
- **Full Mission Assessment**
  - Blue-on-Red and Red-on-Blue Mission Assessment
- **Electronic Warfare**
  - RF Jamming, Communication Jamming, GPS Denial
- **Manned and Unmanned Air Vehicles**
  - Fighter/Bomber, RPA, Integrated Ops
- **Intelligence, Surveillance, Reconnaissance**
  - Integrated Air & Space ISR with DCGS effects*
- **Integrated Air Defense Systems**
  - Real-time Integrated IADS
  - Manned/Unmanned Displays, ECM/ECCM effects

Overview

Engineered Environment

AFLCMC … Providing the Warfighter's Edge

Rqmts Development



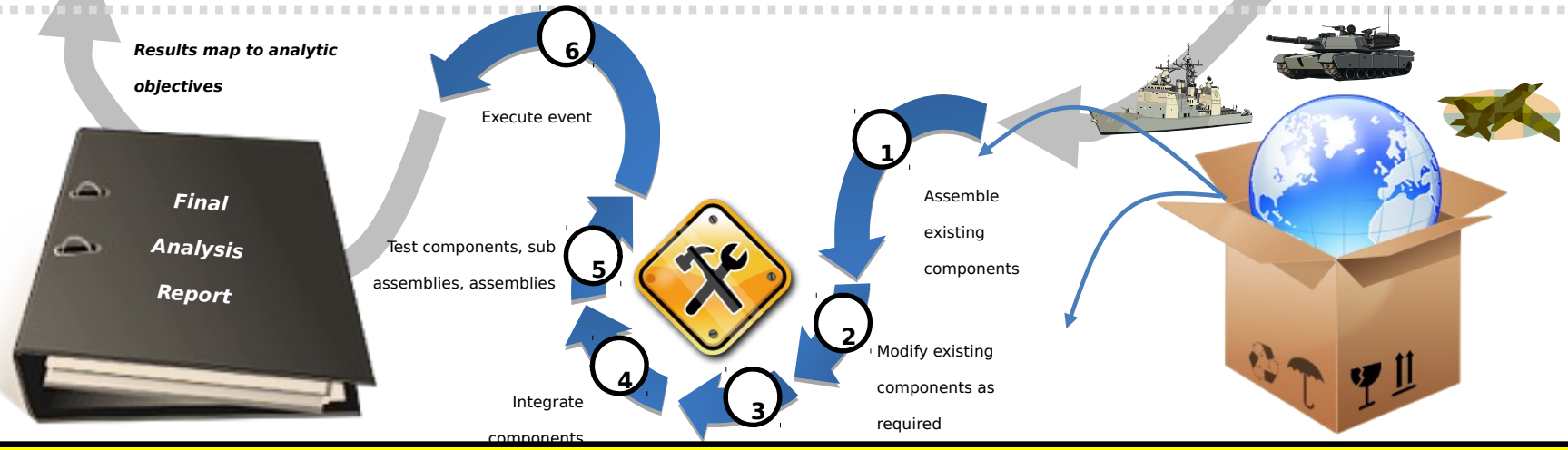
Operational context

Ops environment and intended use, Design the experiment (TAP)

Defined by Experiment objectives

Defined by individual system requirements

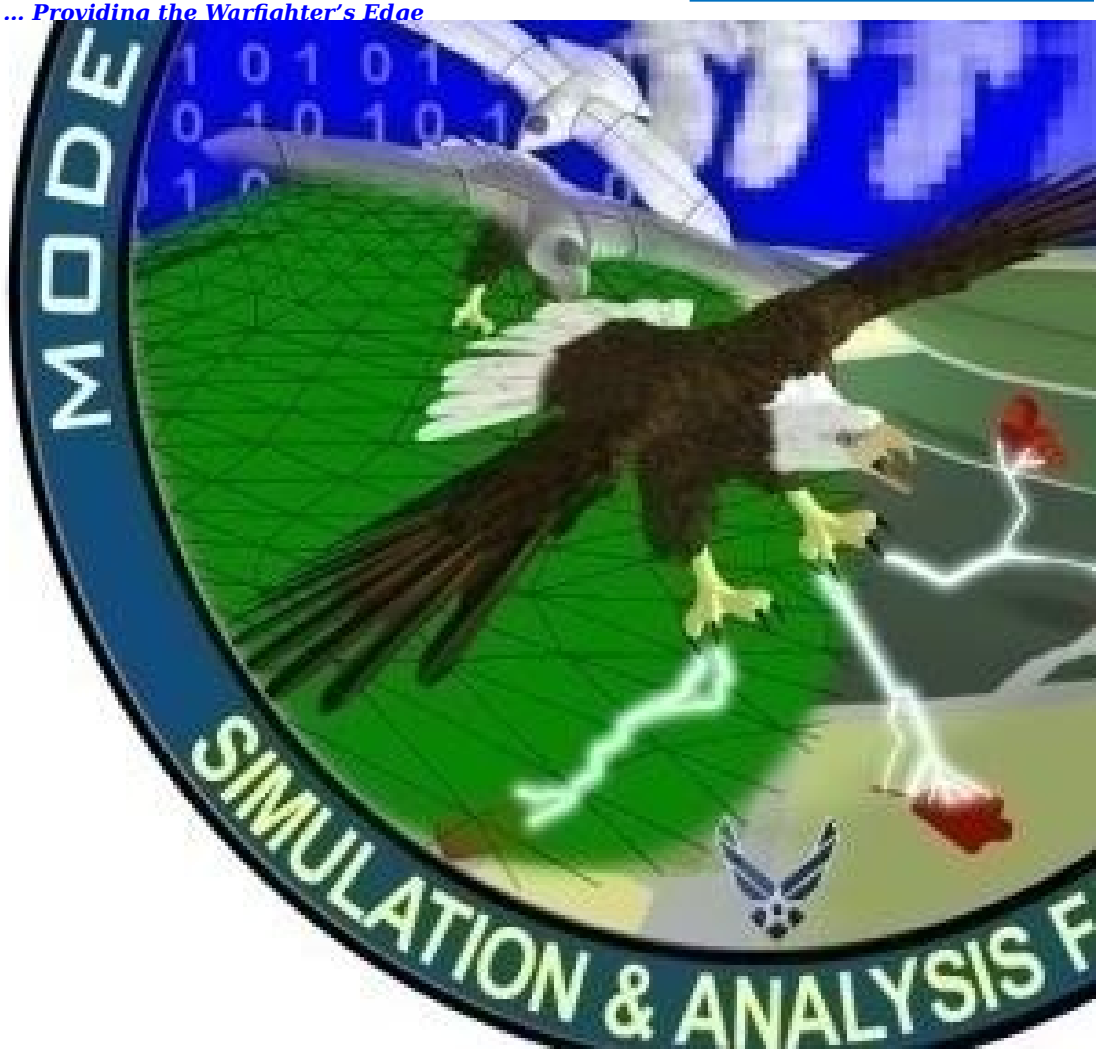
S/W Development



Product of 7 years of applied systems engineering process development! We cut our cycle time in half! We uniquely design the LVC environment for every study!

Outline

- **Overview**
  - Mission
  - Analysis Cycle
  - Capability Focus Areas
  - SE Processes
- **Projects**
  - ANI repository
  - ISR data repository
  - Human Interfaces
- **Vision**
  - Where we are headed & Why?
- **Summary**



Projects

Infrastructure- AF M&S ANI Repository

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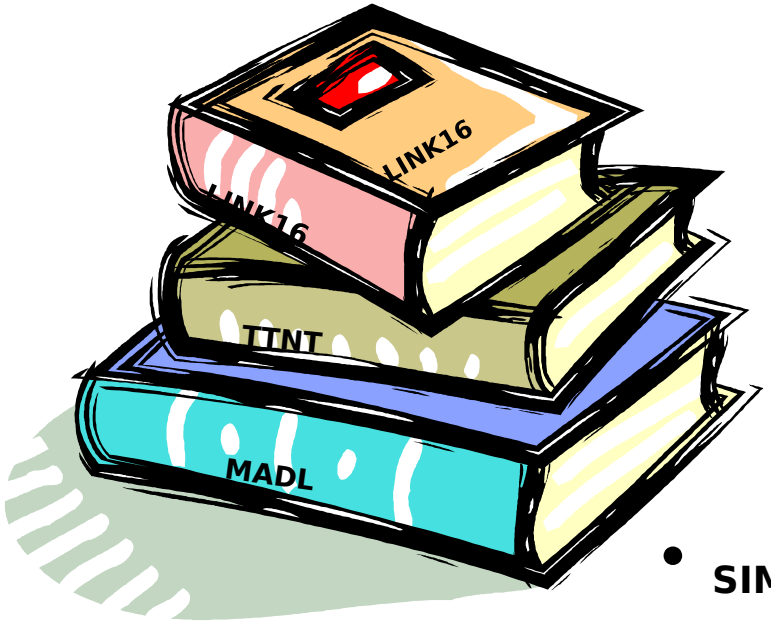

- **GAP: AF need for data link models to support Live-Virtual-Constructive (LVC) assessments of AF Enterprise Interoperability requirements**
- **SIMAF created "real-time" emulative Quality models known as "Terminal Model Applications" or "TMAs"**
- **"TMAs" support operator-in-the-loop mission based assessments and can run with hardware at the Data Link Test Facility (DTF) located at the 46th TS @ Eglin AFB**

Projects

Infrastructure- AF ISR Data Repository

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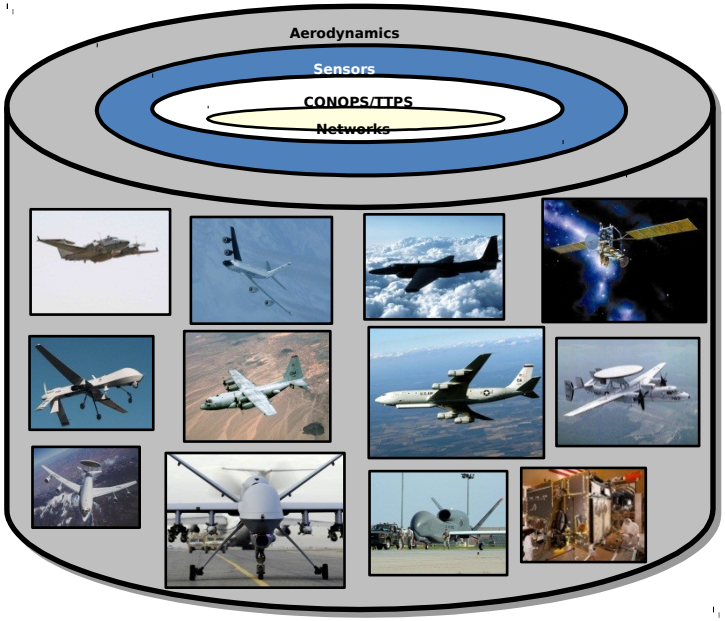

- **GAP: AF need for validated & sustained ISR database to support Air Force Studies**
- **SIMAF was tasked, by HAF/A2, to build and sustain an ISR database for the AF**
- **Database will support FY13 and beyond studies and serve to support other analysis organizations throughout the Air Force**

Projects

Infrastructure- Human Interfaces/Cockpits

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Low Cost Reconfigurable Cockpits

Support Program and Enterprise DP Trades

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Controller Models in SIMAF

Building Blocks of Interoperability Assessment

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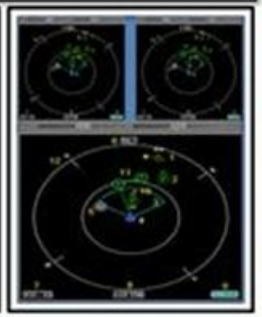
- Ops assessment with variable force mix
- Quick investigation of CONOPs/TTPs
- Dynamically alter the mission/Env.
- Efficient use of Limited Manpower
- Designed to support NCW, EW, etc…



#	Capability	Type	Description
1	5th Gen Lone Controller		
2	4th Gen Lone Controller		
3	Tanker Orbit Controller		
4	JFACC		
5	JFMCC		
6	Gateway UAS Controller		
7	Observer		
8	Space ISR Controller		
9	Bull Pen Controller		
10	Airborne C2 Controller		
11	Multi-ship ISR controller		
12	Sea Lane Controller		
13	JFLCC		
14	Threat IADS Commander		
15	Threat Air Controller		
16	Threat Forces Controller		
17	Multi Weapons		

Enterprise Perspective Interactive Controllers (EPIC) allow for a single operator to control multiple entities within the battle-space providing an "Operational Perspective".

Distributed Teaming

Development and Assessment

U.S. AIR FORCE

SIMAF/46th TS

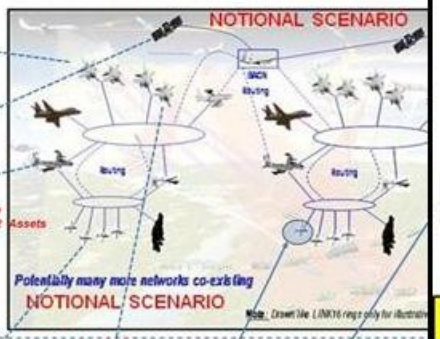
Simulation and Analysis Facility

AFC2IC

AF Command & Control Center

Link/replace with Live C2 Assets

NOTIONAL SCENARIO



Key

- Live
- Virtual
- Constructive
- Capability GAP

Link with Live Assets

Replace with Live Assets

46th TW

46th TS@Eglin AFB

Projects

Distributed Studies – AGILE* Fire

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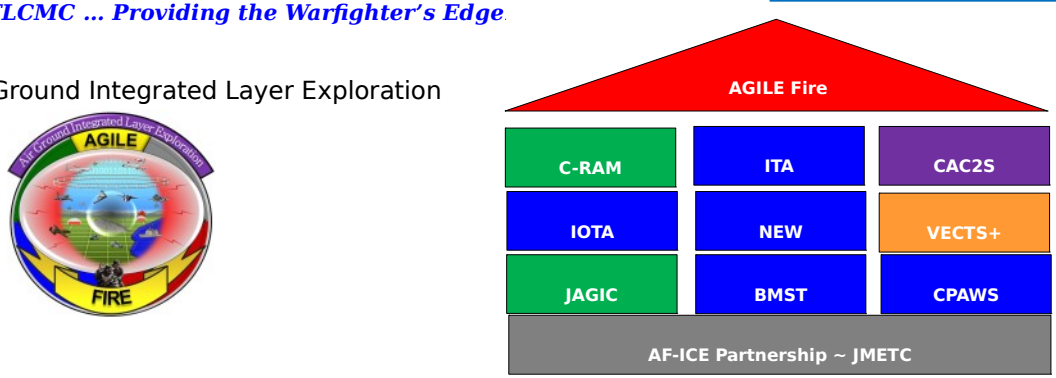
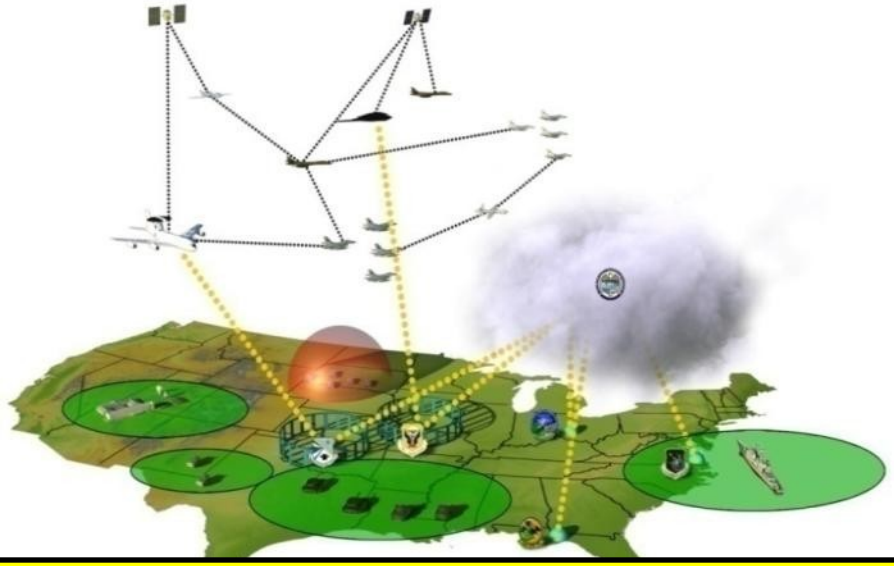
*Air Ground Integrated Layer Exploration

The AF-ICE team is built on a solid partnership between test ranges (live), simulation facilities (virtual), and industry/government models (constructive).





1. **Common Theme:** Explore system interoperability, integration procedures and information exchange requirements *within and between* space, air and ground domains to execute *operational realistic mission threads.*

2. **Event Objective**: AGILE provides a cost effective, *analytically based* experimental venue to allow customers to share assessment costs while benefiting from multiple enterprise related programs and initiatives.

3. **ROI:** The Return on Investment is maximized by focusing the venue on

Success Criteria

- Quantifiable IMPACTS to the participants: AGILE Fire testing finds system interoperability gaps!
- Cost effective: Services pay for their own participating infrastructure. Programs bring their data!
- Value added: Repeat Customers, Problems found and fixed; Combat success!

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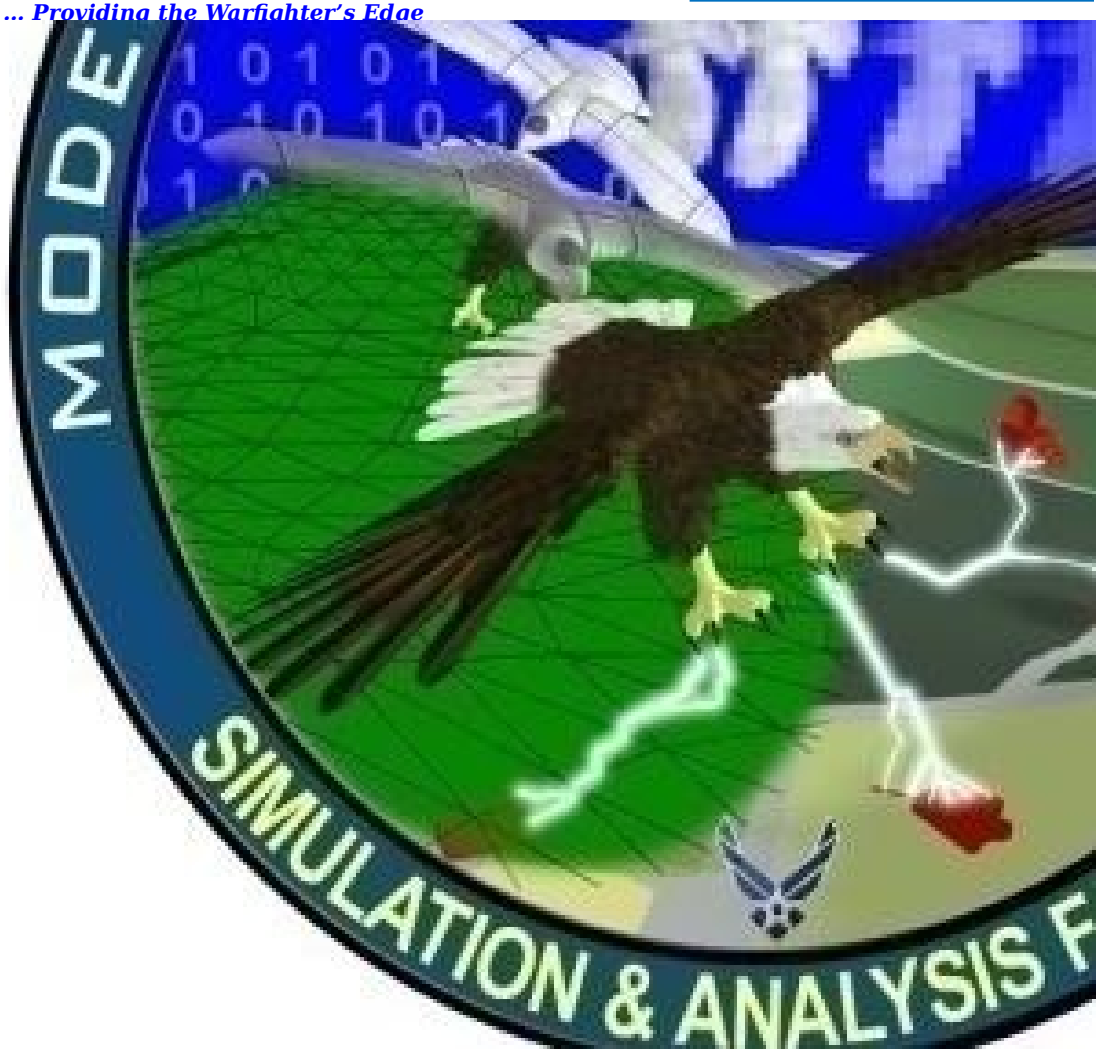

Vision: Top Level Study Schematic

Strategic Assessment

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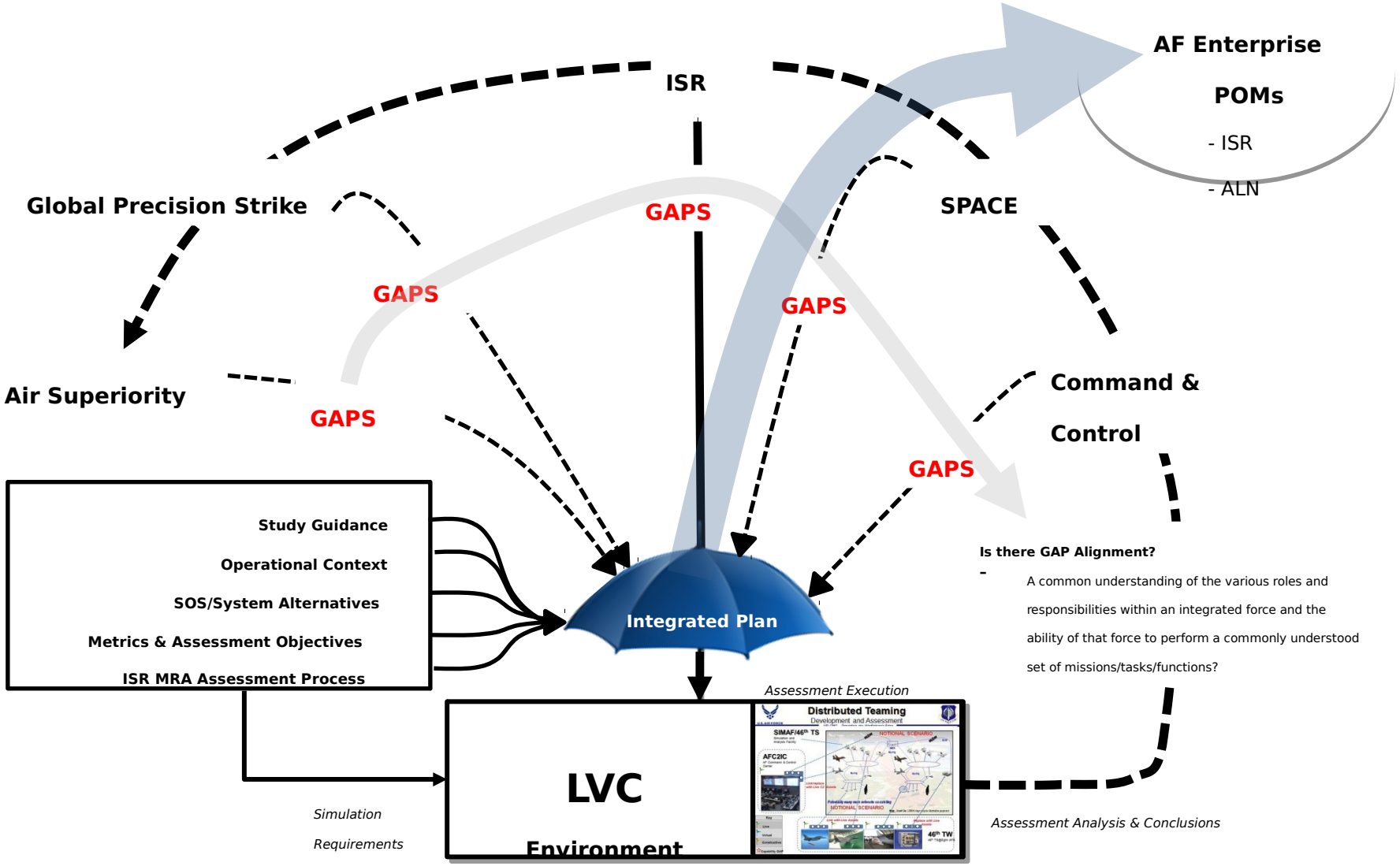

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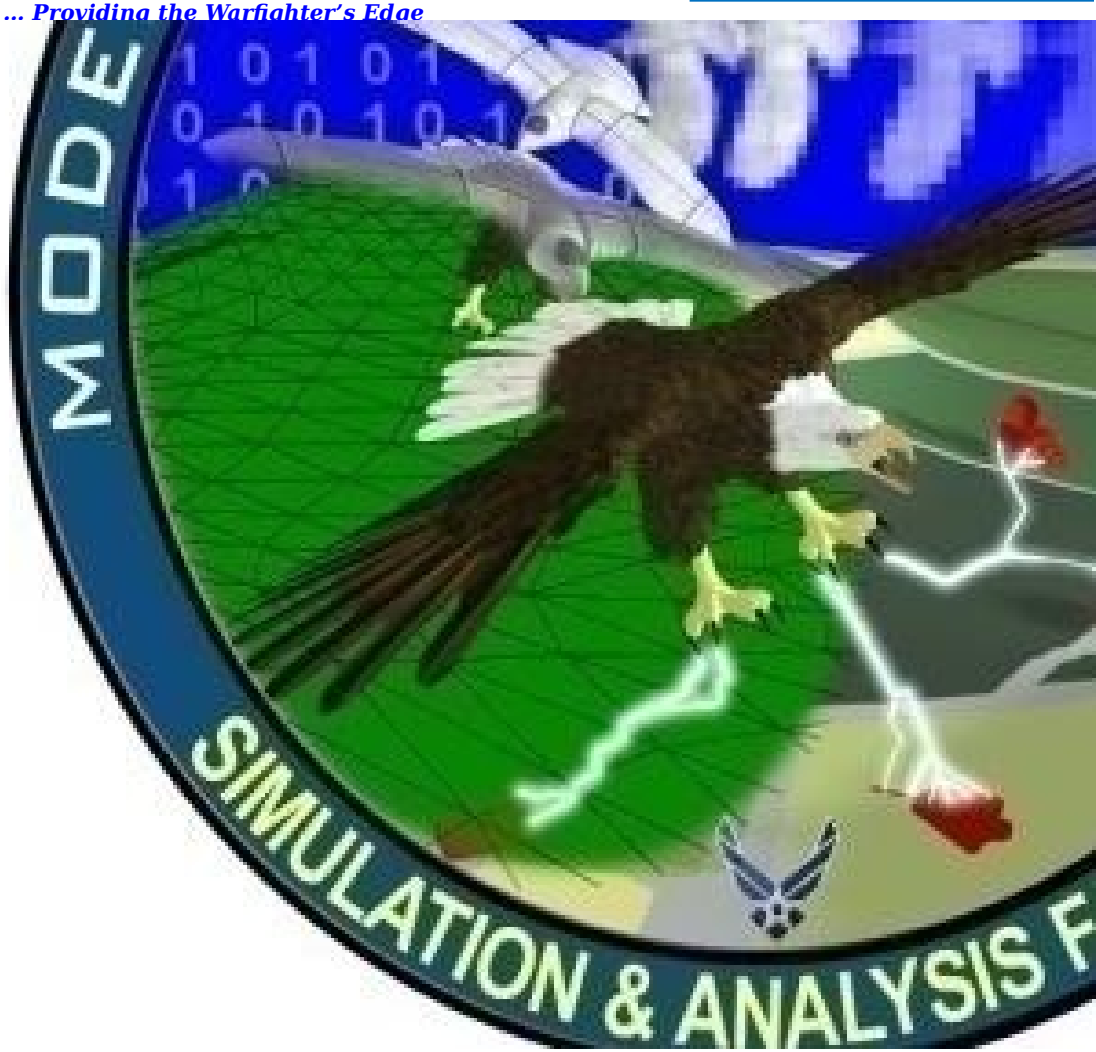

Summary

- **SIMAF views itself as an integration "center"**
  - An enabler for integrated capabilities to emerge
  - War-Fighters, Technologies, Industry to converge on "solutions"
  - Integrated Cross Domain Capabilities
- **Vision: Stand up a Government V-I-C Capability**
  - Salient test is whether Prime Weapon System Contractors are comfortable allowing their proprietary data in the facility.
  - Ideal environment is a well designed federation of Contractor models within a Government Environment
  - Consistent with other AF and DOD approaches
- **Concrete steps in FY14 towards that goal**
  - Broader analytic focus including support for the ISR Enterprise
  - SIMAF is working with the AF team to develop that process
  - ISR Focus is also consistent with DOD approaches

Work has begun! Laying out the Path! Using the AF Team!

Short Break

Start	End	Topic	Presenter
08:30	08:35	Security	Mike Langerman, DARPA SID
08:35	08:40	Welcome	Craig Lawrence, DARPA PM
08:40	09:00	DARPA STO Overview	Nils Sandell, STO Director
09:00	10:00	DBM Concept	Craig Lawrence, DARPA PM
10:00	10:20	SIMAF Overview	Walt March, SIMAF
10:20	10:40	Short Break	
10:40	11:40	Q&A Session	Craig Lawrence, DARPA PM
11:40	11:50	Closing Remarks	Craig Lawrence

Agenda

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Closing

- Key Dates
  - Posting Date: February 21, 2014
  - Industry Day: February 28, 2014
  - Questions Due Date: March 7, 2014
  - Proposal Abstract Due Date: March 11, 2014
  - Proposal Due Date: April 22, 2014

- Email address: DARPA-BAA-14-17@darpa.mil

- STO's BAA Website: http://stobaa.darpa.mil